By Joseph A. Hevesi, Alan L. Flint, and Lorraine E. Flint

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This report presents the development and application of the distributed-parameter watershed model, INFILv3, for estimating the temporal and spatial distribution of net infiltration and potential recharge in the Death Valley region, Nevada and California. The estimates of net infiltration quantify the downward drainage of water across the lower boundary of the root zone and are used to indicate potential recharge under variable climate conditions and drainage basin characteristics. Spatial variability in recharge in the Death Valley region likely is high owing to large differences in precipitation, potential evapotranspiration, bedrock permeability, soil thickness, vegetation characteristics, and contributions

to recharge along active stream channels. The quantity and spatial distribution of recharge representing the effects of variable climatic conditions and drainage basin characteristics on recharge are needed to reduce uncertainty in modeling ground-water flow. The U.S. Geological Survey, in cooperation with the Department of Energy, developed a regional saturated-zone ground-water flow model of the Death Valley regional ground-water flow system to help evaluate the current hydrogeologic system and the potential effects of natural or human-induced changes. Although previous estimates of recharge have been made for most areas of the Death Valley region, including the area defined by the boundary of the Death Valley regional ground-water flow system, the uncertainty of these estimates is high, and the spatial and temporal variability of the recharge in these basins has not been quantified.

To estimate the magnitude and distribution of potential recharge in response to variable climate and spatially varying drainage basin characteristics, the INFILv3 model uses a daily water-balance model o meters in the north-south and east-west directions. The elevation values from the DEM were used with monthly regression models developed from the daily climate data to estimate the spatial distribution of daily precipitation and air temperature. The elevation values were also used to simulate atmospheric effects on potential evapotranspiration, to develop topographic parameters to simulate the effects of shading on potential evapotranspiration, and to develop parameters to simulate surface-water flow. Surface-water flow was modeled as a downstream redistribution of runoff generated by rain or snowmelt and was routed across all the model grid cells as a daily surface-water run-on component of the water balance (for days when runoff was generated) using an eight-directional (D-8), convergent-flow routing algorithm. A six-layer root-zone system--five soil layers and one bedrock layer--was used to simulated the daily root-zone water balance, including evapotranspiration, infiltration, drainage, and redistribution of moisture in the root zone. Evapotranspiration from each root-zone layer was modeled as a function of potential evapotranspiration, the estimated root density for each layer, and the simulated water content for each layer. Downward drainage through each layer was modeled as a function of soil saturated hydraulic conductivity, soil texture, and the simulated water content. Snowfall, sublimation, and snowmelt were modeled as functions of the spatially distributed daily climate input and the simulated solar radiation component of the potential evapotranspiration model.

The model was calibrated using comparisons of (1) simulated streamflow with historical streamflow data from 31 gaging stations in the Death Valley region, and (2) simulated 50-year (1950-99) basinwide average net infiltration with previous estimates of basinwide average recharge for 42 basin areas (defined in previous studies as hydrographic areas and subareas) in the Death Valley region. Parameters adjusted during model calibration included bedrock saturated hydraulic conductivity, root density, average storm duration (for summer and winter storms), and soil saturated hydraulic conductivity and wetted area used to represent stream-channel characteristics. Model calibration using the streamflow records was difficult because the spatial coverage of the daily climate records for many locations in the Death Valley region is not sufficient for simulating local-scale, high-intensity summer storms. In addition, calibration results based on streamflow were sensitive to the parameters representing stream-channel characteristics, and these characteristics were assumed (and thus highly uncertain). Comparison of simulated basinwide net infiltration with previous basinwide estimates of recharge provided better calibration results than comparisons using simulated and measured streamflow. Overall calibration of the INFILv3 model incorporated the results from both methods of calibration because of the uncertainty of the previous estimates of recharge and because of the need to develop independent estimates of potential recharge.

The 50-year INFILv3 simulation results for four different models (where model differences were defined by differences in input parameters were evaluated using a comparison of net-infiltration estimates with the streamflow records and the previous basinwide recharge estimates for the 42 hydrographic areas and subareas. For the model providing the best overall calibration, a total net-infiltration estimate of 413,000 m^3/d was simulated for the total area covered by the 42 hydrographic areas and subareas; this estimate is in good agreement with the total estimated basinwide recharge of 431,000 m^3/d for the same area. The net-infiltration results generally are consistent with the recharge estimates, although net infiltration had less variability on a basinwide scale. Basinwide net-infiltration volumes are lower than recharge volumes for most of the hydrographic areas and subareas that have high recharge estimates and higher than recharge for most hydrographic areas and subareas that have low recharge estimates. The model comparisons indicate that simulated daily streamflow is sensitive to uncertainty in estimates of storm duration, stream-channel characteristics, and bedrock hydraulic conductivity. Net infiltration is sensitive to uncertainty in bedrock hydraulic conductivity and parameters controlling evapotranspiration (such as root density). Both streamflow and net infiltration are sensitive to uncertainty in spatially distributed precipitation and estimated soil thickness.

For the model providing the best overall calibration, model application results for the Death Valley regional ground-water flow system (based on the 1950-99 simulation) include an average net infiltration rate of 2.8 millimeters per year (mm/yr), or a total potential recharge volume of 342,000 cubic meters per day (m^3/d). The simulated potential recharge is 1.6 percent of the 1950-99 simulated average annual precipitation rate of 171.3 mm/yr. Net-infiltration results for individual model cells were highly variable across the Death Valley regional ground-water flow system, with a maximum net-infiltration rate of 1,262 mm/yr for an active stream-channel location. Simulation results also include an average runoff-generation rate of 2.2 mm/yr and an average run-on infiltration rate of 2.0 mm/yr, indicating that most of the runoff infiltrates back into the root zone during downstream routing (as run-on) rather than discharging to playas. Infiltration from surface-water run-on accounts for about 14 percent of the total net-infiltration volume for the Death Valley regional ground-water flow system. However, in some areas of the regional flow system, surface-water flow may contribute as much as 40 percent to the total net-infiltration volume. The simulated average surface-water inflow into playa lakebeds is 0.20 mm/yr and is assumed to evaporate from the playas.

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